

## Claims

To be secured by United States Letters Patent, what is claimed is:

1. A method of recognizing objects under various lighting conditions comprising the steps of:
  - (a) providing a database comprising a plurality of three dimensional models,
  - (b) providing an input image,
  - (c) positioning each three dimensional model relative to the input image,
  - (d) determining, for each three dimensional model, a rendered image which is most similar to the input image, said determining step comprising:
    - (i) deriving a reflectance function that describes an approximation of the set of all possible rendered images that each three dimensional model can produce under all possible lighting conditions, said rendered images including both diffusely and broadened-specularly reflected light; and

- (ii) optimizing the reflectance function to  
determine rendered image of each model  
that is most similar to the input image;
- (e) computing a measure of similarity between the  
input image and each optimal rendered image;  
and
- (f) selecting the three dimensional model  
corresponding to the optimal rendered image  
whose measure of similarity is most similar to  
the input image.

2. The method according to Claim 1 wherein the  
reflectance function employs a model of broadened-  
specular reflectance that accounts for the angle  
between the direction of observation and the  
direction of perfect specular reflectance.
3. The method according to Claim 2 wherein the  
reflectance function further employs a broadened-  
specular reflectance model, said broadened-specular  
reflectance model axially symmetric about the axis  
of perfect specular reflection.
4. The method according to Claim 3 wherein the  
reflectance function includes a mathematical term to

account for the portions of the incident light not contributing to the reflected light due to the position of the object model.

5. A method of deriving the reflectance function of an object model under a variety of lighting conditions, the object model comprising a plurality of surfaces, each of the surfaces defining a normal vector pointing perpendicularly outward, the method comprising the steps of:

- (a) rendering, for a given orientation of the object model, a plurality of images produced by the object model when illuminated by each of a plurality of spherical harmonic components of incident light, wherein said rendering comprises:

- (i) calculating the intensity of incident light components upon the object model, relative to the normal at each surface;
    - (ii) calculating the intensity of light components diffusely reflected by the model toward the observer;

(iii) calculating the intensity of light components broadened-specularly reflected toward the observer, relative to the observer's angle with respect to the angle of perfect specular reflection; and

(b) defining a reflectance function for the object as a linear combination of said plurality of images.

6. The method according to claim 5, wherein said plurality of images comprises nine images produced by the 0<sup>th</sup>, 1<sup>st</sup>, and 2<sup>nd</sup> order spherical harmonic components of incident light.
7. The method according to claim 5, wherein steps of calculating the intensity of light diffusely and specularly reflected towards the observer further comprises employing a broadened-specular reflectance model, said broadened-specular reflectance model axially symmetric about the axis of perfect specular reflection.
8. The method according to claim 5 wherein the reflectance function mathematically accounts for the portions of the incident light not contributing to

the reflected light due to the position of the  
object model.